4 TRIAL BATCH DEMONSTRATION

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CHAPTER FOUR:
TRIAL BATCH DEMONSTRATION

PURPOSE

A trial batch demonstration (TBD) is required for each proposed mix design for QC/QA superstructure concrete. The purpose of the TBD is much more than validating the required concrete properties to be within the specification requirements for the concrete mixture. The TBD also provides an opportunity for the Contractor's Certified Concrete Technician and the Departments Qualified Technician to verify proper equipment calibration and testing procedures prior to any concrete placement in the structure. The Contractor and the PE/PS should both be assured that QC testing will accurately represent the concrete for any process control decision and Acceptance testing will assess the proper adjustment points, if any. Failure to accomplish this at the TBD can result in inaccurate assessment of adjustment points or erroneous failed material investigations when job concrete is placed

The results from a successful TBD can provide the Contractor with baseline properties from which to plan process control of the concrete mixture. Future changes in properties of aggregates, pozzolans, cements, and admixtures can also be compared to the results at the time of the TBD so effects on concrete properties the day of placement can be anticipated.

The TBD also provides an opportunity for the Contractor and Engineer to witness the process upstream from the plant (i.e. material receipt, storage, and handling), through batching and actual concrete production. The complete process should be inspected to provide insight as to any potential process control problems prior to job placement. A properly conducted TBD can work to resolve many problems, which would otherwise become evident on the day of the deck's construction.

PREPARATION

Scheduling a TBD is dependent on several key items, which are as follows:

1. Both the Contractor's Certified Concrete Technician and the Departments Qualified Technician are to be present.

2. The PE/PS must concur with the concrete mix design and proportioning submitted by the Contractor. This includes review of the Contractor's testing of bulk specific gravity (SSD) and absorption properties for the fine and coarse aggregate (see pages 3-16 through 3-18).

3. Adequate time must be allocated to complete the trial batch demonstration. Experience has shown that a properly conducted TBD will typically require 4-6 hours to complete. A poorly planned TBD or questionable mix design will substantially increase the length of the TBD by several hours or even days.

A TBD is not to be used for mix design experimentation or development. The Contractor and his concrete supplier must have sufficient experience in preparing a mix design for workable concrete that will perform as expected during the TBD. Problems should be few, if any, and only of a minor nature.

PROCEDURE

A two-page form has been developed which outlines a systematic approach to conducting a proper trial batch demonstration. Proper use of this form by both the Contractor and Department has proven to be a critical element in progressing through a TBD successfully in the shortest amount of time.

Aggregate Properties

Once the preliminary information is entered at the top of the form the first major task is to evaluate the properties of the fine and coarse aggregate to be incorporated into the concrete. The absorption values for fine and coarse aggregate were determined by the Contractor's sampling and testing and were submitted as part of the mix design and proportioning. It is imperative that the Department concurs with these values prior to the TBD. An example of how to initiate the use of this form is shown in Table 4.1.

AGGREGATE PROPERTIES

Properties	Contractor Result	INDOT Result
FA Bulk Sp. Gr. (SSD)	**2.632**	-NA-
FA Absorption	**2.0** %	-NA-
FA Moisture	%	%
FA Gradation	(attached)	(not required)
CA Bulk Sp. Gr. (SSD)	**2.711**	-NA-
CA Absorption	**1.4** %	-NA-
CA Moisture	%	%
CA Gradation	(attached)	(not required)
Agg. Correction Factor	%	%

Table 4.1

The Certified and Qualified Technicians must obtain samples of the fine and coarse aggregate, of sufficient quantity, to test for moisture content and aggregate correction factor. The moisture contents are to be used in Water/Cementitious Ratio determination. Additional samples of the fine and coarse aggregate must also be obtained by the Contractor's representative for gradation analysis, and possibly bulk specific gravity and absorption determination

The samples should be representative of the aggregates that will actually be batched in the QC/QA superstructure concrete. If the plant is equipped with moisture probes it would be very beneficial for the samples to be from material passing over the probe so a check can be made on the accuracy of the moisture meter. Subsequent changes in the moisture meter prior to batching would then serve as a basis for adjusting the moistures originally measured by AASHTO T 255. If there are no probes to monitor moisture in the aggregates, it becomes more critical that batching contain the aggregates that were accurately represented by the samples. In such a situation it is beneficial for the TBD to occur on a day when production for commercial and/or other state work is minimal. The moisture content results between the Certified and Qualified Technicians must be fairly close otherwise there would be too much of a discrepancy in the Water/Cementitious Ratio. The TBD should not progress until discrepancies are resolved.

An example of how the aggregate properties might look on the form is presented in Table 4.2.

AGGREGATE PROPERTIES

Properties	Contractor Result	INDOT Result
FA Bulk Sp. Gr. (SSD)	**2.632**	-NA-
FA Absorption	**2.0** %	-NA-
FA Moisture	**6.8** %	**6.6** %
FA Gradation	(attached)	(not required)
CA Bulk Sp. Gr. (SSD)	**2.711**	-NA-
CA Absorption	**1.4** %	-NA-
CA Moisture	**2.3** %	**2.5** %
CA Gradation	(attached)	(not required)
Agg. Correction Factor	%	%

Table 4.2

The Aggregate Correction Factor may be determined at this time; however, it may be a more effective use of time to conduct the test during the agitation period after batching and mixing the QC/QA concrete which simulates the delivery time. It is critical that testing be done by both the

Certified and Qualified Technicians to establish an accurate value to be used in air content measurement. Aggregates in Indiana have been found to range from a value of 0.1 to 1.0. It should be noted that aggregates having a high absorption do not necessarily correlate to a high aggregate correction factor.

Concrete Batching & Mixing

The next step is to progress to the table on the form entitled "Concrete Batching". The mix design batch weights are simply transferred to the second column of the table as exemplified in Table 4.3.

Materials	Design Batch Wts. (SSD Agg. Wts.) lbs
Cement	**658**
Pozzolan	**------**
Silica Fume	**------**
FA	**1211**
CA	**1742**
Water	**260**
∑	**3871**

Table 4.3

The next column on the form identifies what the aggregate batch weights would be in a completely dry condition. This is calculated by dividing the SSD aggregate weight by 1 plus the absorption (as a decimal).

Example: $1211 \div (1 + 0.020) = 1187$ lbs FA Dry Wt.

$1742 \div (1 + 0.014) = 1718$ lbs CA Dry Wt.

These numbers are inserted in the form as illustrated by Table 4.4 for the example problem.

Target batch weights can now be determined based on the moisture content of the aggregates. This is calculated by multiplying the dry aggregate batch weights by 1 plus the moisture content (as a decimal).

Example: $1187 \times (1 + 0.068) = 1268$ lbs FA Moist Wt.

$1718 \times (1 + 0.023) = 1758$ lbs CA Moist Wt.

Table 4.5 shows how these numbers would be entered on the form. It is important to note that the moisture content determined by the Contractor's Certified Technician is used in establishing target batch weights for aggregates.

Materials	Design Batch Wts. (SSD Agg. Wts.) lbs	Dry Aggregate Batch Weights lbs
Cement	658	-NA-
Pozzolan	--------	-NA-
Silica Fume	--------	-NA-
FA	1211	**1187**
CA	1742	**1718**
Water	260	-NA-
∑	3871	-NA-

Table 4.4

Materials	Design Batch Wts. (SSD Agg. Wts.) lbs	Dry Aggregate Batch Weights lbs	Target Batch Wts. (Moist Agg.Wts.) lbs
Cement	658	-NA-	**658**
Pozzolan	-------	-NA-	**--------**
Silica Fume	-------	-NA-	**--------**
FA	1211	1187	**1268**
CA	1742	1718	**1758**
Water	260	-NA-	
∑	3871	-NA-	

Table 4.5

The target batch weight for mix water must be reduced by the amount of free water provided by the aggregates. The difference between the aggregate batch weights in a moist condition and the saturated surface dry condition gives the proper result.

Example: 1268 - 1211 = 57 lbs free water from fine aggregate

1758 - 1742 = 16 lbs free water from coarse aggregate

57 + 16 = 73 lbs free water contributed by aggregates

The amount of free water contributed by the aggregates must be subtracted from the water content of the mix design to obtain the target.

Example: 260 - 73 = 187 lbs mix water target

Table 4.6 illustrates where to enter target batch weight for water on the form for the example problem. The summation of all target batch weights for each component is also entered.

Materials	Design Batch Wts. (SSD Agg. Wts.) lbs	Dry Aggregate Batch Weights lbs	Target Batch Wts. (Moist Agg.Wts.) lbs
Cement	658	-NA-	658
Pozzolan	-------	-NA-	--------
Silica Fume	-------	-NA-	--------
FA	1211	1187	1268
CA	1742	1718	1758
Water	260	-NA-	**187**
∑	3871	-NA-	**3871**

Table 4.6

It is important to note that the moist aggregate weight may not always be above the weight representing a saturated surface dry condition. It is more likely to happen with a crushed stone coarse aggregate, particularly if that material is produce by a dry crushing operation. If the moisture content of an aggregate is below the absorption value, then aggregate free water becomes a negative amount and additional mix water may be needed to batch concrete at the target water/cementitious ratio.

At this point it should be recognized that many computerized batching systems utilize what is termed "free moisture content" which is different from total moisture content. Free moisture is the amount of moisture in the aggregate beyond the saturated surface dry condition; where as, total moisture content is the amount of moisture in the aggregate beyond the totally dry condition. Dealing with differences in percentages results in target batch weight being slightly higher, and mix water requirement being slightly lower (i.e. 1269 lbs FA, 186 lbs water for the example problem). The difference becomes more pronounced as total moisture content increases.

A plant which operates using free moisture content of aggregates will result in a target water content that is slightly conservative (i.e. slightly lower water/cementitious ratio).

The next step is for the Contractor's representative to establish a target batch size of concrete to make. The batch must be sufficiently large to account for the limited accuracy of the scales at low weights. A minimum size of 3 yd^3 to 4 yd^3 is recommended. A lesser batch might otherwise be out of tolerance creating a yield problem or mix that does not represent the intended design.

The total batch weight of each ingredient to be charged into the mixer is calculated next by multiplying the target batch weights by the target batch size. The example problem values are presented in Table 4.7.

Materials	Target Batch Wts. (Moist Agg.Wts.) lbs	Target Batch Size yd^3	Total Target Batch Wts. lbs	Actual Batch Wts. lbs	Error ± %
Cement	658	**4.0**	**2632**		
Pozzolan	-------	**4.0**	**--------**		
Silica Fume	-------	**4.0**	**--------**		
FA	1268	**4.0**	**5072**		
CA	1758	**4.0**	**7032**		
Water	187	**4.0**	**748**		
∑	3871	-NA-	-NA-		-NA-

Table 4.7

It is highly recommended that the total batch weight calculated for each component be checked against the values that the batch plant operator intends to use. This should even be done with a computerized batching operation. Miscommunication or errors in control panel settings can quickly create significant delays in time and effort. The amount of water to be batched by the plant may intentionally be reduced by the amount of water to be used in washing down the funnel and fins of the transit mixing truck. This amount of water, which is typically 25-42 lbs, can have a significant effect on water/cementitious ratio in a reduced size batch of 3 to 4 yd^3.

Once the total batch weights are confirmed as being correct, the ingredients can be weighed and recorded in the column entitled "Actual Batch Weights." The percentage error between the total target batch weight and the actual batch weight is recorded in the last column of the form. This is calculated by subtracting the total target batch weight from the actual batch weight and divide by the total target batch weight. Multiply this number by 100 to determine the percentage.

Example: [(2625 - 2632)/2632] x 100 = – 0.3 % error in cement batching
Table 4.8 illustrates data entry on the form for all ingredients.

Materials	Target Batch Wts. (Moist Agg.Wts.) lbs	Target Batch Size yd^3	Total Target Batch Wts. lbs	Actual Batch Wts. lbs	Error ± %
Cement	658	4.0	2632	**2625**	**– 0.3**
Pozzolan	-------	4.0	--------	**--------**	**-----**
Silica Fume	-------	4.0	--------	**--------**	**-----**
FA	1268	4.0	5072	**5040**	**– 0.6**
CA	1758	4.0	7032	**7060**	**+ 0.4**
Water	187	4.0	748	**741**	**– 0.9**
∑	3871	-NA-	-NA-	**15466**	-NA-

Table 4.8

The same procedure is used for the air entraining and chemical admixtures as well.

At this stage of the TBD, it must be determined whether the batched concrete represents the intended proportioning of the mix design. Batching tolerance must be within the requirements of 702.06, which is:

Material	Required Accuracy
Cement	± 1%
Aggregates	± 2%
Water	± 1%
Admixtures	± 3 %

The example problem, presented in Table 4.8, would therefore be within the allowable error and the batch would be considered representative of the intended design.

After batching, the concrete is to be mixed for the appropriate number of revolutions of the drum at mixing speed. Once mixing is completed, the truck is to remain at agitation speed for a period of 15-45 minutes before testing.

Concrete Testing

It may be advantageous for the Contractor to conduct a series of tests on the plastic concrete after completion of the mixing cycle. This testing provides initial information on the slump, air content, and unit weight, which can then be compared to the testing conducted after the simulated transit time. Although the specification requires a minimum Air Content of 5.0% at the TBD, the Contractor may prefer a higher air content if there

are concerns about compressive strength. If the air content is less than the desirable result the Contractor may wish to add additional air entraining agent (AEA) to the mixed load of concrete in an effort to increase air content. However, this is difficult to accomplish since it typically takes a large dosage of air entraining agent to increase the air content only a few tenths of a percent. Additional water may be used to assist in dispersal of the AEA within the mixed concrete; however, it must be measured accurately and recorded as part of the batch water. If more than one adjustment is needed to obtain the desired air content the truckload should be rejected and another batch prepared.

At the end of the 15-45 minute agitation time, the concrete is tested by the Certified Concrete Technician and the Qualified Technician. Both parties must test the concrete for the specified plastic properties and cast at least four cylinders for compressive strength determination at 7 and 28 days.

The test results are to be reported on page 2 of the TBD form. Table 4.9 is an example of how the plastic properties would be recorded.

CONCRETE TESTING

Plastic Property	Contractor Quality Control Technician	INDOT Acceptance Sampler	Tolerance Check	Third Party Results
W/(C+P)	**0.392**	**0.394**	**+0.002**	
Unit Wt. (lbs/ft^3)	**146.0**	**145.9**	**–0.1**	
Air Content (%)	**5.8**	**5.7**	**–0.1**	
Slump (in)	**6.00**	**6.25**	**+0.25**	
Relative Yield	**0.981**	**0.982**	-NA-	

Table 4.9

A tolerance check is made between results from the two parties and is recorded in the appropriate column. Table 4.9 exemplifies comparative results that are well within tolerance.

A fifth column is included on the form for recording test results from a third party, should the situation arise. These results are for information only but may help to solve problems if results are out of tolerance.

The next table on page 2 of the form deals with comparison of measured unit weight with the predicted value established by the linear equation for the mix design. The predicted unit weight is calculated by simply entering the measured air content in the linear equation. Recalling the example CMD linear equation from Chapter 3 would provide the following calculations.

Example: Contractor's Predicted UW = −1.54 (5.8)+153.4 = 144.5 lbs/ft^3

Department's Predicted UW = −1.54 (5.7)+153.4 = 144.6 lbs/ft^3

Comparison of predicted values with their respective measured unit weight provides an easy determination of how close the batched concrete represents the intended CMD. The tolerance check of the example illustrates non-compliance with the specification requirements for a TBD, as Table 4.10 illustrates.

LINEAR EQUATION

	Predicted Unit Weight lbs/ft^3	Measured Unit Weight lbs/ft^3	Tolerance Check ± %
Contractor Rep.	**144.5**	**146.0**	**+1.0**
INDOT Rep.	**144.6**	**145.9**	**+0.9**
Third Party			

Table 4.10

If the tolerance checks of predicted versus measured unit weight is outside the specification limits, an investigation by the Contractor and PE/PS is required. If the concrete was accurately batched, mixed, sampled, and tested, the most likely cause would be an inaccurate moisture content, bulk specific gravity, or absorption for one, or both of the aggregates.

If the moisture content were actually higher than what was expected, the measured unit weight would be lower than expected. If the moisture content were actually lower than what was expected, the measured unit weight would be higher.

The relationships presented in Table 4.11 can be useful in estimating the effect on unit weight and water cementitious ratio for a variety of causes. The total effect on concrete unit weight or water cementitious ratio is cumulative from the individual causes. The values tabulated below are representative of a typical mix having 40% fine to total aggregate ratio:

Possible Causes	**Effect on Concrete Unit Weight**	**Effect on Concrete W / (C+P)**
Limits of Batching Tolerance	Δ ± 0.3 lbs/ft^3	**Δ ∓ 0.007**
Δ ± 0.030 in FA Bulk (SSD)	Δ ± 0.5 lbs/ft^3	None
Δ ± 0.5 % in FA Absorption	Δ ± 0.3 lbs/ft^3	**Δ ∓ 0.009**
Δ ± 0.5 % in FA Moisture	Δ **∓ 0.3** lbs/ft^3	Δ ± 0.008
Δ ± 0.030 in CA Bulk (SSD)	Δ ± 0.6 lbs/ft^3	None
Δ ± 0.5 % in CA Absorption	Δ ± 0.5 lbs/ft^3	**Δ ∓ 0.013**
Δ ± 0.5 % in CA Moisture	Δ **∓ 0.5** lbs/ft^3	Δ ± 0.012

Table 4.11

Additional testing for aggregate moisture content and/or bulk specific gravity (SSD) and absorption may very well be required to resolve a concrete unit weight measurement being outside the tolerance from the linear equation, as encountered in the example problem.

The compressive strength cylinders must be cured and transported properly to the testing laboratory. It is imperative that the specimens be clearly identified as to which mix design and TBD they represent. The age at which the specimens are to be broken must also be clearly identified for the laboratory. Cylinders that are broken at an age of 7-days provide early age strength capability of the CMD and may be indicative of a 28-day strength result that will not meet the minimum specification requirement or the expectations of the Contractor. The tolerance check between specimens cast by Certified and Qualified technicians is conducted on the 28-day strength only. An example of recording the test data on page 2 of the form is shown in Table 4.12.

COMPRESSIVE STRENGTH

Age In Days	Contractor's Lab Result psi		INDOT District Lab Result psi		Tolerance Check ± %
	Specimen	Average	Specimen	Average	
7	**4770**	**4820**	**4310**	**4360**	-NA-
7	**4870**		**4410**		-NA-
28	**5990**	**6035**	**5600**	**5665**	**–6.1 %**
28	**6080**		**5730**		
					-NA-
					-NA-

Table 4.12

An additional row is provided at the bottom of the table for test results on additional cylinders that may be tested at an age other than the minimum specified.

The PE/PS's concurrence with a CMD requires that the trial batch demonstration be successfully completed. The Contractor's test results shall be used to validate the mix as complying with the specification requirements. The Department's results must be within the specified tolerance of the Contractor's results. Any test result that is not within tolerance is to be investigated by both parties as to the cause and corrective actions needed to resolve the discrepancy.